NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

THESIS

BASE REALIGNMENT AND CLOSURE ACTION SCHEDULER (BRACAS)

by

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September, 1995

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE September 1995	3. REPORT TYPE AND DATES COVERED Master's Thesis

4. TITLE AND SUBTITLE BASE REALIGNMENT AND CLOSURE ACTION SCHEDULER (BRACAS)

5. FUNDING NUMBERS

6. AUTHOR(S) Chen-Guan Wong

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)*

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14. SUBJECT TERMS Base Realignment and Closure, Scheduling, Mixed Integer Programming

15. NUMBER OF PAGES 60

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18 298-102

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BASE REALIGNMENT AND CLOSURE ACTION SCHEDULER (BRACAS)

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Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1995

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ABSTRACT

This thesis develops a mixed integer linear optimization model, BRACAS, to help construct optimal implementation schedules for base realignment and closure actions. Given a list of installations for realignment and closure, BRACAS maximizes the net present value of future savings less the one-time costs while satisfying yearly budget constraints. BRACAS provides insights on the adequacy of the budget and tradeoffs between budget and savings. Modeling issues that have impact on further use of the model such as "solution persistence" and alternate computation of savings are examined. With solution persistence incorporated, BRACAS is capable of generating an optimal revised schedule that maintains continuity with a previous schedule. Between June and August 1995, BRACAS helped the Army Base Realignment and Closure Office determine budget levels and implementation schedules for the 1995 round of base realignments and closures.

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EXECUTIVE SUMMARY

The end of the Cold War and the large U.S. budget deficit has led to dramatic reductions of the U.S. military. Fewer forces require fewer installations. By eliminating unnecessary facilities, limited defense funds can be channeled to vital military needs. Balancing the installation structure with the new force-structure will make the Department of Defense more efficient and enhance national security. The U.S. Army's recommended closures and realignments for the 1995 round of Base Realignment and Closure (BRAC 95) have been finalized and must be completed within six years. A systematic approach is needed to optimally schedule the slated installations for closure or realignment such that the savings are realized as early as possible while still ensuring that the one-time cost needed for the actions are within yearly budgets.

This thesis develops a mixed integer linear program to optimally schedule installation realignments and closures referred to as the Base Realignment and Closure Action Scheduler (BRACAS). BRACAS determines when to allocate the necessary one-time costs of installation closure and realignment actions to obtain the maximum net present value of the savings less the one-time costs while satisfying yearly budgets.

This thesis shows how BRACAS can be used to provide insights on the adequacy of the budget given an approved list of installation closure and realignment actions. It can be used to determine the tradeoffs between budget and savings and the budget requirements under constrained and unconstrained budget limits. This versatility makes BRACAS a useful

tool for the implementation of the approved BRAC actions.

This thesis also examines modeling issues that have impact on further use of BRACAS. "Solution persistence" is incorporated into BRACAS to produce an optimal revised schedule that takes into account decisions and actions that have already been made. Such modeling is necessary since schedules are often revised when there are updated cost estimates. This thesis also provides insights for the user on how the changes in the schedule vary with the level of "persistence" and how it affects the budget when the changes are reduced to a minimum.

A different formulation of savings due to closure or realignment of installations can produce different results. BRACAS currently uses a step savings function which restricts decision variables to a few integer values. A piecewise savings function that uses some continuous decision variables was found to reduce computational requirements while producing schedules comparable to the step function.

Between June and August 1995, BRACAS helped the U.S. Army Base Realignment and Closure Office determine budget levels and implementation schedules for the 1995 realignments and closures. At the time of writing this thesis, the model has undergone further changes to meet their changing needs. This underscores the need for the model to be adaptable to new requirements and changes while it is being used.

I. INTRODUCTION

A. BACKGROUND

The end of the Cold War has altered the military threats posed by the Soviet Union and its allies. These events have had dramatic impacts on U.S. military requirements. In addition, the large U.S. budget deficits provides an impetus to cut U.S. military spending. Therefore, the Department of Defense (DoD) is decreasing the U.S. military to adapt to new realities. Fewer forces require fewer installations. By eliminating unnecessary facilities, limited defense funds can be channeled to vital military needs. Balancing the installation structure with the new force-structure plan will make DoD more efficient and enhance national security.

Public Law 100-510 created the Defense Commission on Base Realignment and Closure (BRAC). The law empowered the Commission with recommending installations for closure or realignment based on an independent study of the domestic military installation structure. Eliminating excess infrastructure and consolidating functions has been an ongoing process to bring the installation structure in line with the declining force structure. The 1988, 1991 and 1993 BRAC rounds recommended the closure of 250 military installations and the realignment of 152 others installations [BRAC, 1993]. Despite these installation closures and realignments, there is still excessive capacity in the installation structure. This leads to the 1995 round of the BRAC process and the Commission has recommended the closure or realignment of 132 installations at an estimated one-time cost of $3.5 billion [BRAC, 1995].

B. BRAC PROCESS

It is necessary to understand the process and the methodology used in the BRAC process before defining the problem of this thesis. The description of the Army's BRAC process in this section is taken from the 1995 Commission report [BRAC, 1995]. The Army established the Total Army Basing Study (TABS) office to make recommendations for potential installation closures and realignments to the Army Chief of Staff and Secretary of the Army. TABS employed a two-phased process to make recommendations on installation closures and realignments. First, TABS arranged installations into 11 categories based on the primary mission, and then analyzed the military value of each installation within its category. Military value was based on five measures of merit - mission essentiality, mission suitability, operational efficiency, quality of life, and expendability. From this analysis, TABS identified its candidates for further study. TABS developed closure and realignment alternatives which they subjected to a cycle of analysis based on feasibility, affordability, socioeconomic impacts, environmental impacts, and the subjective pros and cons of each alternative.

For the analysis of the closure and realignment alternatives, the Office of the Secretary of Defense has specified that the "Cost of Base Realignment Actions" (COBRA) [Richardson and Kirmse Incorporation, 1994] model must be used to calculate costs, savings, and return on investment of proposed closures and realignments [BRAC, 1993, p.20-22]. Return on investment is the expected payback period in years for each proposed installation closure or realignment. The output data from COBRA was used by all the Services and Defense Agencies in their decision making process [BRAC, 1995].

Finally, TABS determined its recommendations which were ultimately delivered to the Secretary of the Army and the Army Chief of Staff who forwarded the recommendations to the Secretary of Defense. Upon endorsement by the Secretary of Defense, the recommendations were submitted to the Commission for review. The Commission reviewed the Secretary of Defense's recommendation and made changes when it found a "substantial deviation" between the recommendation and the Secretary's force-structure plan and the final criteria approved by Congress. The Commission forwarded its final report to the President and his decision became final when Congress did not vote within 45 days to overturn it.

All BRAC 95 Commission recommendations must be implemented within six years. A relatively large one-time investment is required to close an installation before future savings can be achieved. To provide for this investment, Congress established the Base Closure Account. This account provides funds for military construction, relocation expenses, environmental cleanup costs, and other one-time costs that are incurred as a result of installation closure or realignment. The one-time investment is justified by potentially large future recurring savings that can be achieved by closing installations.

C. PROBLEM DEFINITION

Throughout the BRAC process, there is no systematic way of scheduling the selected installations for closure or realignment such that the savings are realized as early as possible while still ensuring that the one-time cost needed for the actions are within the budget constraints. Free (1994) developed an optimization model (BRAC model) to optimally schedule installation realignments and closures. His model determines when to allocate the

necessary one-time costs of installation realignment and closure actions to obtain the maximum net present value of the savings less the one-time costs while satisfying yearly budgets. He demonstrated with the Army's BRAC 93 recommendation that the model produced a savings increase of 34% compared to the schedule manually constructed with COBRA. Although Free's model generated a lot of interest in TABS, it was not incorporated in the BRAC analysis as the budget was not a concern during the BRAC 95 planning stage.

Now that the recommendations for installation realignments and closures have been approved, a tool is needed to produce an optimal schedule that maximizes the savings less the one-time costs while satisfying the budget constraints. Free's model could meet this need but several improvements can help to produce more realistic schedules. This thesis develops a Base Realignment and Closure Action Scheduler (BRACAS) as an extension to Free's model. The schedule produced by BRACAS contains a detailed breakdown of costs for each closure and realignment action. BRACAS also takes into account the construction lead time before allowing closing and realignment activities to take place.

In addition to making changes to Free's model, this thesis also examines relevant modeling issues that have impact on further use of BRACAS. "Solution persistence" is incorporated into BRACAS to produce an optimal revised schedule that takes into account decisions and actions that have already been made. Such modeling is necessary since schedules are often revised when there are updated cost estimates. This thesis also provides

insights for the user on how the changes in the schedule vary with the level of "persistence" and how it affects the budget when the changes are reduced to a minimum.

A different formulation of savings due to closure or realignment of installations can produce different results. The current formulation uses a step function which restricts decision variables to a few integer values. The thesis examines a piecewise cost function that allows continuous decision variables to be used.

Finally, the thesis also shows how BRACAS can be used to provide insights on the adequacy of the budget given an approved list of installation closure and realignment actions. It can be used to determine the tradeoffs between budget and savings and the budget requirements under constrained and unconstrained budget limits. This versatility makes BRACAS a useful tool for the implementation of the approved BRAC actions.

1. Modeling Approach

1. Given the slated BRAC actions (i.e., a complete list of gaining and losing installations), the model generates an optimal schedule of actions with the objective of maximizing total net savings within budgetary constraints.

2. The model facilitates analysis of the tradeoffs between budget and savings.

3. The model takes into account decisions and actions that have already been made when generating a revised schedule with updated data; the goal is to keep changes to a minimum.

4. The model facilitates the analysis of tradeoffs between changes in the revised schedule and the budget.

5. The thesis examines an alternate formulation using a piecewise cost saving function and determines how this affects the results.

D. THESIS OUTLINE

Chapter II surveys the operations research literature for work closely related to the subject of this thesis. Chapter III provides an extensive description of BRACAS, its assumptions, and its features. Chapter IV uses the Army's closure and realignment recommendations for BRAC 95 as a test case for BRACAS and provides analysis of model results. Finally, Chapter V presents the conclusions and ideas for future model enhancements.

II. BRAC MODEL AND RELATED WORKS

This chapter describes Free's model and its potential uses in greater detail. Other works and research related to the modeling issues addressed in this thesis are examined. Their applicability and shortcomings as related to the specific problem are also discussed.

A. BRAC MODEL

All Services and Defense Agencies are required to use COBRA to calculate costs, savings, net present value, and return on investment for installation realignment and closure actions falling under the thresholds established in Public Law 101-510. COBRA output data was used by each of the Services and Defense Agencies to make a relative comparison of different alternatives based on the NPV of the savings less the one-time cost. The NPV of the net savings is based on user-defined inputs as to when specific actions and spending occur. For example, the user is required to enter the personnel, equipment, and vehicles moving in each of the scenario years for each pair of installations. Similarly, the user must specify the exact amount of the one-time costs to be spent in each of the scenario years. COBRA then calculates the total expected savings of the scenario based on this specific sequence of actions. Since different user-defined inputs can result in entirely different outputs, COBRA does not guarantee the "best" solution to any closure or realignment scenario. A systematic approach is needed to optimally schedule actions for BRAC scenarios in order to begin realizing savings as soon as possible within the budgetary constraints.

The need for an optimal schedule provided the impetus for Free (1994) to develop an optimization model to schedule BRAC actions within budget limits. For the model to be acceptable to the TABS decision makers, the model inputs and the assumptions were consistent with COBRA. Using a mixed integer programming model generated by the General Algebraic Modeling System (GAMS) [Brooke, 1994] for an actual BRAC 93 scenario, Free (1994) demonstrated that optimization achieved a 34% increase in savings over the manual schedule developed by TABS. Additionally, the model facilitates determining whether a set of proposed closures and realignments is in fact feasible under budgetary constraints, and if not, what the budget shortfall is. Budget sensitivity analysis also allows a determination of how sensitive a proposed scenario is to budget reductions; this supports rapid "what if" assessments.

The model could be extremely useful in developing closure and realignment recommendations. Since all Services use COBRA during the cost-benefit analysis phase, it is possible that the model could be incorporated in the analysis to rapidly determine if a set of proposed closures and realignments is feasible under budgetary constraints.

The BRAC 95 process is over and the recommended list of installations for closure and realignment have been approved. The next step is to implement the slated actions in an optimal manner so as to maximize the savings less the one-time cost while satisfying budget constraints. There are no approved models for the process. Free's model with extensions is a possible candidate to meet this need. This leads to the BRACAS model developed in this thesis.

B. CAPITAL BUDGETING PROBLEM

The capital budgeting problem refers to the problem of selecting a subset of programs, projects, investment packages, etc., from a given set, within a certain framework of budgetary and other resource limitations. It is also known as the project selection problem. The objective is to maximize the payoff of the projects selected while satisfying the resource limitations over the time horizon under consideration. Weingarter (1963) develops a systematic approach for bringing integer programming techniques to bear on certain fundamental aspects of capital budgeting with the intent of paving the way for eventual application to more concrete problems. Recent work by Brown, Clemence, Teufert and Wood (1991) applies the technique to the optimization model for modernizing the Army's Helicopter Fleet. Clark, Hindelang and Pritchard (1989) provides a comprehensive description of the methods for capital budgeting. This includes net present value, integer programming and goal programming for capital budgeting. The problem where all projects must be completed is a variation of the capital budgeting problem.

C. PERSISTENCE

Optimization has a well-earned reputation for amplifying small changes in input data into enormous changes in output. This can be catastrophic in installation closing actions as decisions once made have far reaching impacts and cannot be easily changed. "Persistence" involves encouraging one solution of a mathematical program to be similar to a previous solution or to be similar to a solution that the decision maker prefers. Optimization models often represent systems for which some plans already exist, or for which some plans will exist

after a model run or two, and prescribed actions must reflect the cost of changing existing plans. Professors G.G. Brown, R.F. Dell and R.K. Wood of the Naval Postgraduate School have mathematically formalized and implemented in a practical fashion several versions of "solution persistence" between related linear programming and mixed-integer programming models. Different forms of persistent modeling techniques were demonstrated in scheduling Coast Guard District Cutters [Brown, Dell, and Farmer, 1995], optimizing submarine berthing [Brown, Cormican, Lawphongpanich and Widdis, Draft] and anti-armor weapon systems acquisition [Ihde, 1995]. The techniques were adapted to BRACAS to achieve "solution persistence" when the model is run with updated data.

III. BRACAS MODEL

This chapter describes BRACAS, its assumptions and formulation as an extension of the model found in [Free, 1994]. BRACAS is a mixed integer programming model. The BRACAS objective is to maximize NPV while ensuring all costs necessary to accomplish the base closures and realignments over six years are within budgetary constraints. BRACAS incorporates assumptions and details that lead to a realistic schedule for implementation. It provides insight on the adequacy of the budget and facilities tradeoffs between budget and savings. This chapter also gives a description of how BRACAS is capable of generating an optimal revised schedule that maintains continuity with the previous schedule.

A. DATA CONSISTENCY

The first consideration is for BRACAS inputs to be consistent with the inputs used in COBRA. This is to ensure that all the data necessary to run this model can be obtained from the COBRA runs conducted during the planning phase of the BRAC process. Since there is a large amount of data, assumptions have been made to combine them into smaller groups in order to reduce the number of variables in BRACAS. This was closely coordinated with TABS to ensure that the resulting model would still be capable of meeting their specific needs. The assumptions about the data that is extracted from the COBRA runs are in Appendix A.

B. SAVINGS COMPUTATION

1. Nonlinear Function

The objective of BRACAS is to maximize the net present value of savings resulting from the closure and realignment of installations. A major modeling issue is to establish the relationship between savings and closure or realignment actions. COBRA uses a convex nonlinear function, Equation (1), to compute savings for various stages of base closure.

$$SAVINGS = BASE\ EXPENSES * \left(1 - \left(\frac{New\ Population}{Old\ Population} \right)^{0.3} \right) \tag{1}$$

2. Step Function

A nonlinear function in a linear integer program is not desirable as it usually takes an unacceptable amount of time to solve. An approximation used in the BRAC model and by BRACAS is the step function, Equation (2). Define the binary variables $THIRD1_{tlg}$, $THIRD2_{tlg}$ and $DONE_{tlg}$ to be one when at least one third, at least two thirds, and all of the closure or realignment activities from installation l to g (lose-gain pair) is complete by year t. The step-function assumes that the savings are one quarter, half and all of the total savings when the installation is one-third, two-third and completely closed respectively. This simplification underestimates the savings obtained from Equation (1) but allows BRACAS to be modeled as a mixed integer program that can be solved efficiently.

$$TOTAL\ SAVINGS = \sum_{t} \sum_{lg} RECURRENTSAVING_{lg} * \frac{1}{4} (2\ DONE_{tlg} + THIRD1_{tlg} + THIRD2_{tlg}) \quad \textbf{(2)}$$

The next step in BRACAS development is to establish the relationship between the one-time costs and the transition activities. Close consultations were held with TABS to understand how various BRAC costs interact and how they were allocated and executed in previous BRAC actions. BRACAS assumes that the transitional actions of the base closure and realignments actions are proportional to the cumulative amount of the one-time costs paid. Define $ALLMOVE_{tlg}$ and $REALIGN_{lg}$ as the one-time cost to be paid for actions involving installations l and g in year t and the total one-time costs respectively. Equation (3) shows that in any year, the closure or realignment status can be one-third, two-third or complete only if the proportional amount of the one-time costs have been allocated.

$$\frac{\sum_{t=1}^{t'} ALLMOVE_{tlg}}{REALIGN_{lg}} \geq \frac{1}{3} (\ DONE_{t'lg} + THIRD1_{t'lg} + THIRD2_{t'lg}\ ) \quad \forall\ t',\ lg \qquad \textbf{(3)}$$

3. Piecewise Linear Function

The step cost function is discontinuous and restricts stages of base closures to values of 1/3, 2/3 and 1 only. A continuous and linear function removes this restriction and can lead to greater flexibility in deciding the stages of closure during the transition period.

The piecewise linear savings function considered is a linear function with a step increase. Define a new variable P_{tlg} to represent the proportion of BRAC actions completed for a lose-gain pair of installations at time period t. P_{tlg} replaces $THIRD1_{tlg}$ and $THIRD2_{tlg}$ variables in the previous formulations while the $DONE_{tlg}$ variable remains. The gradient of the linear function is set at 3/4 so that when the BRAC actions are 1/3 and 2/3 complete, the savings are 1/4 and 1/2 respectively which are consistent with the step savings function. The piecewise linear savings function in Equation (4) ensures that the savings from the BRAC actions are proportional to the amount of transitional activities completed and the remaining savings are achieved when all actions are completed.

$$TOTAL\ SAVINGS = \sum_{lg} \sum_{t} RECURRENTSAVING_{lg} \cdot \left(\frac{1}{4} DONE_{tlg} + \frac{3}{4} P_{tlg}\right) \qquad \textbf{(4)}$$

Savings increase proportionally with the amount of activities closed or realigned and increase sharply when all actions are completed. The sharp increases when all activities are completed is to account for savings accruing from cessation of critical activities such as security and medical services which are the last activities to be terminated. Due to partial rewards allocations, we expect schedules from the new savings function under constraining budgets to have more fractional installation closures earlier compared to the step function that is encouraged to fully fund a few actions. To relate cost to actions, the constraint in Equation (5) ensures that the cost of moving is proportional to the amount of BRAC actions completed.

$$\frac{\sum_{t=1}^{t'} ALLMOVE_{tlg}}{REALIGN_{lg}} \geq P_{t'lg} \quad \forall\ t',\ lg \tag{5}$$

C. CONSTRUCTION ACTIVITIES

Construction costs comprise over 50% of the total one-time costs (based on the BRAC 95 Army recommendations) and so they must be modeled carefully. The assumptions underlying the modeling of construction activities in BRACAS are as follows:

1. Activities can only be moved from a closing installation to the gaining installation in proportion to the percentage of required military construction completed.
2. Construction activities once started must be completed within a specified number of years.
3. Costs of construction are allocated according to fixed rules.

BRACAS assumes that all payment must be made at the beginning of the construction period. For multiple year construction projects, 9% must be paid in the first year for design and the remaining amount is paid in the second year. Define the following parameters and variables:

<u>Data</u>

CON-Y_g - number of years for the construction activities at installation g;

CON-C_g - cost of construction at installation g;

REQ_g - the percentage of personnel and freight that can move onto installation g without any new military construction at g.

Variables

$CONCOM_{tg}$ - equals 1 if construction at installation g is completed in year t, 0 otherwise;

$$\begin{aligned} COST\ AT\ YEAR\ t = & \sum_{g:\ CON\text{-}Y_g = 1} CON\text{-}C_g * CONCOM_{t,g} \\ & + \sum_{g:\ CON\text{-}Y_g \geq 2} (0.09\ CON\text{-}C_g * CONCOM_{(t+CON\text{-}Y_g-1),g} \\ & + 0.91\ CON\text{-}C_g * CONCOM_{(t+CON\text{-}Y_g-2),g}) \qquad \forall\ t \end{aligned} \tag{6}$$

$$\sum_{t \geq CON\text{-}Y_g}^{t=6} CONCOM_{tg} = 1 \qquad \forall\ g \tag{7}$$

$$\begin{aligned} & \frac{\sum_{t=1}^{t'} ALLMOVE_{tlg}}{REALIGN_{lg}} \leq 1 - (1 - REQ_g) * \\ & (1 - \sum_{t=1}^{t'} CONCOM_{tg} - \sum_{t \geq t'+1}^{t'+(CON\text{-}Y_g)-1} CONCOM_{tg} * \frac{(CON\text{-}Y)_g-(t-t')}{CON\text{-}Y_g}) \qquad \forall\ t',\ lg \end{aligned} \tag{8}$$

Equation (6) calculates the construction cost at year t which is determined by when the construction project at each installation g is to be started. BRACAS decides the appropriate starting period for the construction based on availability of funds. Constraint (7) ensures that all construction activities must be completed within six years. Constraint (8) ensures that the cumulative percentage of all one-time costs due to closure and realignment

activities at the losing installation does not exceed the cumulative percentage of required military construction completed at that installation modified by REQ_g. REQ_g in the equation represents the excess capacity at the gaining installation where BRAC activities can take place without the completion of the construction activities.

D. TRADEOFF ANALYSIS

To facilitate tradeoff analysis, BRACAS allows the yearly budgets to be exceeded. This is easily incorporated in BRACAS by adding a deficit variable in the budget constraints. The deficit is however strongly discouraged by budget penalties in the objective function and the budget is exceeded only if the increased savings exceeds the penalties incurred. The deficit variable in the objective function allows BRACAS to trade off savings with the budget by an amount controlled by the budget penalty. The economic interpretation of the budget penalty is discussed in Chapter IV.

E. ASSUMPTIONS

The assumptions of BRACAS are listed below.

1. The transition period for an installation undergoing realignment or closure is no more than six years. Therefore, all actions which generate one-time costs or savings must be scheduled to occur no later than the sixth year.

2. An upper limit exists for the budget each year. The budget may be exceeded by BRACAS when sufficient recurring savings are allowed by the violation. A budget penalty controls the degree to which the budget may be exceeded.

3. Any civilian reduction-in-force actions necessitated by the closure or realignment of any lose-gain pair of installations must occur in the last year of the transition period.

4. Military construction started in year t will be completed in year t, t+1, t+2, t+3 as specified. This allows for planning and construction time. Payment for construction is 9% and 91% of total construction cost in the first and second year respectively for all projects requiring two or more years.

5. Recurring savings are the net savings generated each year after the transition period is complete when activities are moved from one installation to the other. Portions of recurring savings can be realized during a transition period year based on what portion of the move is complete. Specifically, one-quarter recurrent savings are realized in transition period years when at least one-third but less than two-thirds of the move is complete, and one-half recurrent savings are realized in the transition period when at least two-thirds of the move is completed.

F. ESSENTIAL ELEMENTS OF BRACAS

The notations used in BRACAS are the same as those used in Free's model whenever possible.

1. Indices

- t,t' year of the closure process (t= 1,..,6),
- l installation which is losing activities or functions,
- g installation which is gaining activities or functions.

2. Data

$CONSAV_l$ all procurement and construction costs avoided as a direct result of realignment of installation l,

$PROGRAM_l$ total program cost (discounted to year one) at installation l,

$PERS\text{-}C_{lg}$ cost of all civilian reduction-in-force actions at losing installation directly attributable to the realignment of functions from installation l to installation g,

$CON\text{-}C_g$	total cost of new military construction and rehabilitation required at installation g due to realignment,
$RSAV_{lg}$	the steady-state recurring savings which accrue yearly at installation l as a result of the realignment of installation l to g,
DEVPEN	the penalty cost imposed for exceeding the budget,
r	discount rate,
REQ_g	the percentage of personnel and freight that can move onto installation g without any new military construction at g,
BUD_t	total funds available for BRAC actions in year t,
$CON\text{-}Y_g$	number of years required for military construction at the gaining installation,
$REALIGN_{lg}$	sum of all movement costs at losing installation l for each lose-gain pair lg,
$GAIN_{lg}$	sum of all one-time costs at gaining installation g for each lose-gain pair lg,
LG	the set of all losing and gaining installations.

3. Variables

a. Binary

$DONE_{tlg}$	equals 1 if the transition period corresponding to the realignment from installation l is complete by the end of year t; 0 otherwise,
$THIRD1_{tlg}$	equals 1 if at least one-third of all personnel required to move from installation l have moved by the end year t; 0 otherwise,

$THIRD2_{tlg}$	equals 1 if at least two-third of all personnel required to move from installation l have moved by the end of year t; 0 otherwise,
$CONCOM_{tg}$	equals 1 if construction is completed in year t at installation g; 0 otherwise,

b. ***Continuous***

$ALLMOVE_{tlg}$	portion of $REALIGN_{lg}$ spending at losing installation l in year t for lose-gain pair lg,
$ALLGAIN_{tlg}$	portion of $GAIN_{lg}$ spending in year t at losing installation g for lose-gain pair lg,
$CIVPER_{tlg}$	portion of $PERS\text{-}C_{lg}$ spending at losing installation l in year t for lose-gain pair lg,
DEV_t	an elastic variable representing the amount by which BUD_t is exceeded in year t,

4. Formulation

$$
\begin{aligned}
MAX\ TOTSAV = & \sum_t \sum_{lg} \frac{RSAV_{lg}}{4} (2\ DONE_{tlg} + THIRD1_{tlg} + THIRD2_{tlg}) \frac{1}{(1+r)^{t+1}} \\
& + \sum_{s=8}^{20} \sum_{lg} (RSAV_{lg}) \frac{1}{(1+r)^s} + \sum_l (CONSAV_l - PROGRAM_l) \\
& - \sum_t \sum_{lg} (ALLMOVE_{tlg} + ALLGAIN_{tlg} + CIVPER_{tlg}) \frac{1}{(1+r)^t} \\
& - \sum_t \sum_{g:CON\text{-}Y_b=1} (CON\text{-}C_g \cdot CONCOM_{tg}) \frac{1}{(1+r)^t} \\
& - \sum_t \sum_{g:CON\text{-}Y_b\geq 2} (0.09 \cdot CON\text{-}C_g \cdot CONCOM_{(t+CON\text{-}Y_g-1),\, g}) \frac{1}{(1+r)^t} \\
& - \sum_t \sum_{g:CON\text{-}Y_b\geq 2} (0.91 \cdot CON\text{-}C_g \cdot CONCOM_{(t+CON\text{-}Y_g-2),\, g}) \frac{1}{(1+r)^t} \\
& - \sum_t (DEV_t \cdot DEVPEN) \frac{1}{(1+r)^t}
\end{aligned}
$$

subject to:

(1)

$$\sum_{lg} (ALLMOVE_{tlg} + ALLGAIN_{tlg} + CIVPER_{tlg})$$
$$+ \sum_{g:CON\text{-}C_g=1} CON\text{-}C_g * CONCOM_{tg}$$
$$+ \sum_{g:CON\text{-}Y_g \geq 2} 0.09 * CON\text{-}C_g * CONCOM_{(t+CON\text{-}Y_g-1),\, g}$$
$$+ \sum_{g:CON\text{-}Y_g \geq 2} 0.91 * CON\text{-}C_g * CONCOM_{(t+CON\text{-}Y_g-2),\, g} \leq BUD_t + DEV_t \quad \forall\ t$$

(2)

$$\frac{\sum_{t=1}^{t'} ALLMOVE_{tlg}}{REALIGN_{lg}} \geq \frac{1}{3}(DONE_{t'lg} + THIRD1_{t'lg} + THIRD2_{t'lg}) \quad \forall \quad t',\, lg \in LG$$

(3)

$$\frac{\sum_{t=1}^{t'} ALLGAIN_{tlg}}{GAIN_{lg}} \geq DONE_{t'lg} \quad \forall \quad t',\, lg \in LG$$

(4)

$$\frac{\sum_{t=1}^{t'} CIVPER_{tlg}}{PERS\text{-}C_{lg}} = DONE_{t'lg} \quad \forall\ t',\, lg \in LG$$

(5)

$$\sum_{t \geq CON\text{-}Y_g} CONCOM_{tg} = 1 \quad \forall \quad g$$

(6)

$$\sum_{t \geq CON-Y_g}^{t \leq t'} CONCOM_{tg} \geq DONE_{t'lg} \quad \forall\ t',\ lg \in LG$$

(7)

$$(a)\ THIRD2_{tlg} \geq DONE_{tlg} \quad \forall\ t,\ lg \in LG$$

$$(b)\ THIRD1_{tlg} \geq THIRD2_{tlg} \quad \forall\ t,\ lg \in LG$$

(8)

$$\frac{\sum_{t=1}^{t'} ALLMOVE_{tlg}}{REALIGN_{lg}} \leq \frac{\sum_{t=1}^{t'} ALLGAIN_{tlg}}{GAIN_{lg}} \quad \forall\ t',\ lg \in LG$$

(9)

$$\frac{\sum_{t=1}^{t'} ALLMOVE_{tlg}}{REALIGN_{lg}} \leq 1 - (1 - REQ_g) *$$

$$(1 - \sum_{t=1}^{t'} CONCOM_{tg} - \sum_{t \geq t'+1}^{t'+CON-Y_g-1} CONCOM_{tg} * \frac{(CON-Y_g)-(t-t')}{CON-Y_g}) \quad \forall\ t',\ lg \in LG$$

The objective function seeks to maximize the NPV of the total savings achieved by the installations slated for closure or realignment over a 20-year period by taking into account both the one-time costs, one-time savings and the long term recurrent savings generated by the closure actions.

Constraint (1) ensures that net expenditures in a given year do not exceed the available budget for that year. The elastic variable DEV_t allows this constraint to be violated at a cost.

Constraint (2) turns on the appropriate indicator variables to ensure that the applicable portion of recurrent savings is realized in years when a sufficient number of personnel or freight have been moved for a particular lose-gain activity.

Constraint (3) ensures that a particular lose-gain action is not complete until all the transitions actions at the gaining installation which generate the one-time costs are complete.

Constraint (4) ensures that all civilian reduction-in-force actions at the losing installation for each lose-gain activity occur in the last year of the transition period.

Constraint (5) ensures that all construction projects must be completed by year six.

Constraint (6) ensures that the BRAC action for a lose-gain pair can be completed only after construction at the gaining installation has been completed.

Constraint (7) ensures that a one-third action is always completed before a two-third action and a two-third action is always completed before a done action.

Constraint (8) represents "linking constraints" which ensure that the total percentage of one-time costs at the gaining installation must be greater than the total percentage of one-time costs at the losing installation for each lose-gain activity.

Constraint (9) ensures that the cumulative percentage of all one-time costs at the losing installation does not exceed the cumulative percentage of required military construction completed at the gaining installation modified by REQ_g.

G. PERSISTENCE FORMULATION

1. Persistence of Solutions

The schedule has to be frequently adjusted in the course of implementing the BRAC actions. This may be due to slippage in some BRAC actions resulting in excess funds that can be channeled to other areas. Or it may be due to an increase in costs for actions in progress that causes some future actions to be delayed. Currently there is no systematic method to make the adjustments.

BRACAS can be used to generate a revised schedule fixing those actions already in progress while rescheduling others and still maximizing the savings under the new circumstances. In a linear model, change in input tends to amplify the outcome and could result in a drastic change in the schedule. Fortunately, there is a modeling technique that allows us to do the rescheduling while keeping the changes to a minimum. The modeling technique is the "solution persistence" technique [Brown, Dell and Wood, 1995] that provides solutions that are similar to the current ones while still near optimal in an optimization program. An adaption of the technique is used in BRACAS to achieve solution persistence.

2. Step Function

Using the step savings function in BRACAS, the optimal schedule produced specifies when the one-time costs are to be paid and the state of the transition is indicated by the $DONE_{tlg}$, $THIRD1_{tlg}$ and $THIRD2_{tlg}$ variables. Changes in the schedule occur when any of the binary variables changes from zero to one or from one to zero.

In "solution persistence", similarity with the current solution is obtained by minimizing deviations between the new and current schedules. To encourage the new schedule to be similar to the current schedule, we penalize changes in the following manner. When the activities are brought forward in time, savings increase but we add a penalty that is a multiple of the savings obtained due to this change. When activities are delayed resulting in a loss of savings, we add a penalty of additional losses that are a multiple of the losses obtained by this delay. These penalties encourage the new schedule to be similar to the current schedule.

Let CURRENT and NEW be the current and new schedules respectively. The penalty function is given in Equation (19). The penalty is zero when there are no changes to the schedule but is a multiple of the savings specified by a persistence factor when there are changes.

$$PENALTY = -(PERSISTENCE * SAVINGS * |NEW - CURRENT|) \qquad \textbf{(19)}$$

To incorporate persistence in BRACAS, the expression in Equation (20) is added to the objective function of the formulation. The expression penalizes deviations from the previous solutions where $ODONE_{tlg}$, $OTHIRD1_{tlg}$ and $OTHIRD2_{tlg}$ represent the current solutions.

$$- PERSISTENCE * \sum_{t} \sum_{lg} \frac{RSAV_{lg}}{4} (2 \mid DONE_{tlg} - ODONE_{tlg} \mid + \mid THIRD1_{tlg} - OTHIRD1_{tlg} \mid + \mid THIRD2_{tlg} - OTHIRD2_{tlg} \mid) \tag{20}$$

Greater persistence can come with a cost which is the violation of the budget constraint. For tradeoff analysis between persistence and the budget, BRACAS allows the yearly budget to increase. Tradeoffs between greater persistence in solutions and increases in budget are guided by the persistence factor.

3. Linear Piecewise Function

We examined how persistence can be incorporated when the savings function is the linear piecewise function. Recall that P_{tlg} represents the proportion of BRAC actions completed for a lose-gain pair of installations at time period t. The changes in the new schedule are measured by Equation (21) where PD_{tlg} and ND_{tlg} measure positive and negative deviations respectively.

$$NEW\, P_{tlg} = CURRENT\ P_{tlg} + PD_{tlg} - ND_{tlg} \tag{21}$$

The penalty function in the objective function is given by Equation (22). The function penalizes deviations from the previous solution by a multiple of the recurring savings controlled by the persistence factor. The penalty is zero when there are no deviations.

$$- PERSISTENCY \sum_{t} \sum_{lg} \Big(RSAV_{lg} * \frac{1}{4} \big(|ODONE_{tlg} - DONE_{tlg}| \big) + RSAV_{lg} * \frac{3}{4} \big(PD_{tlg} + ND_{tlg} \big) \Big) \qquad \textbf{(22)}$$

In this chapter, we described BRACAS, its development and the formulation. In the next chapter, we demonstrate the application of BRACAS to the BRAC 95 list of installations recommended by TABS to the Commission (the Commission subsequently altered the recommendations) and analyze the results.

IV. MODEL IMPLEMENTATION AND ANALYTIC INSIGHTS

This chapter describes the experience of using BRACAS to develop schedules for the Army's BRAC 95 recommended lists of installations for closure and realignments. In addition to producing an optimal schedule, BRACAS can be used to examine questions such as adequacy of the budget and impact on savings when the budget changes.

BRACAS is used under two circumstances: unconstrained and constrained budget. In the unconstrained case, BRACAS is used to determine the schedule and the best possible value for NPV and fund requirements when there are no restrictions on the budget. Years of large expenditures can be identified. In the constrained case, budget restrictions are imposed on some or all years and BRACAS is used to determine the optimal schedule that maximizes NPV savings within these limits. Further runs of BRACAS investigate the tradeoffs between the budget violation and the total NPV savings with the same budget constraints.

It may happen that the original schedule needs to be revised when there are changes to the original cost estimates. The revised schedule should take into account decisions and actions that have been committed and those that have not. It is also desirable that the revised schedule should be similar to the previous solutions for continuity. BRACAS is used to produce a revised schedule that meets the above requirements. For continuity, large changes in the revised schedule are discouraged by penalties in the objective function. Further runs

of BRACAS investigate the tradeoffs between budget increases and the changes made to the original schedule.

A. IMPLEMENTATION

BRACAS was applied to the BRAC 95 Army submissions to the Commission consisting of 43 losing and 38 gaining posts. All results use a discount rate of 4% with 0% inflation (All COBRA results for the BRAC 1995 Commissions recommendations use a 2.75% discount rate with 0% inflation [BRAC, 1995]. In comparative runs, the difference in discount rates has minimal effects). Data input provided by TABS were extracted from COBRA. GAMS [Brooke, 1994] is used to generate the mathematical model, and XA [Byer, 1992] is used to solve the mixed integer linear program. The model has 2,959 variables, 1,464 binary variables, and 2,446 constraints and was solved using a 486/66 Personal Computer. A solution within 5% of optimality was always constructed within 35 minutes.

1. Unconstrained Budget

BRACAS is used to determine the budget requirements when there are unlimited funds. With no budget constraints, it is possible to close all installations immediately except for those with construction lead time at the gaining installations. The savings obtained represents the best possible savings that can be achieved. In BRACAS, this can be easily done by removing the constraint on the yearly budget and allowing BRACAS to determine its own budget requirements.

In the unconstrained case, budget requirements for each year is given by the Table 1. below. Large expenditures fall on years one and two with $411 million each.

Year	1	2	3	4	5	6
Budget	411	411	49	37	10	14

Table 1. Unconstrained Budget Requirements. Requirements are highest in year 1 and 2.

2. Budget Constraint

The funds requirements in the first two years are large and we want to place a limit on the budgets of all the years in order to achieve a balanced distribution. BRACAS schedules those BRAC actions with high net savings early and delays those with low net savings while satisfying the budget limits. The schedule that follows produces maximum NPV savings within the budget restrictions. The NPV for various budget reductions, in terms of percentages of $441 million for year 1 to 3, is given in Table 2 below.

Limit	0 %	10%	15%	20%	25%	30%	35%	40%
Year 1	441	369	375	367	330	302	280	264
Year 2	441	396	359	345	316	289	273	264
Year 3	41	66	88	113	226	230	265	205
Year 4	37	73	83	25	36	80	82	91
Year 5	10	13	11	40	8	8	8	43
Year 6	14	14	15	41	23	25	25	65
NPV savings	6023	6013	6005	5999	5996	5976	5970	5782

Table 2. Net Savings as the Budget Reduces. The reduction is in terms of percentages of the peak unconstrained budget. Savings decline as the budgets get tighter.

The maximum NPV savings is $6,023 million obtained when the budget is unconstrained. This is reduced when budget limits imposed on years 1 to 3 are decreased from $441 million as shown in Figure 1 below. The reduction was less than $50 million for the budget reduction set at less than 35% of $ 441 millions but increases sharply to $250 millions after that.

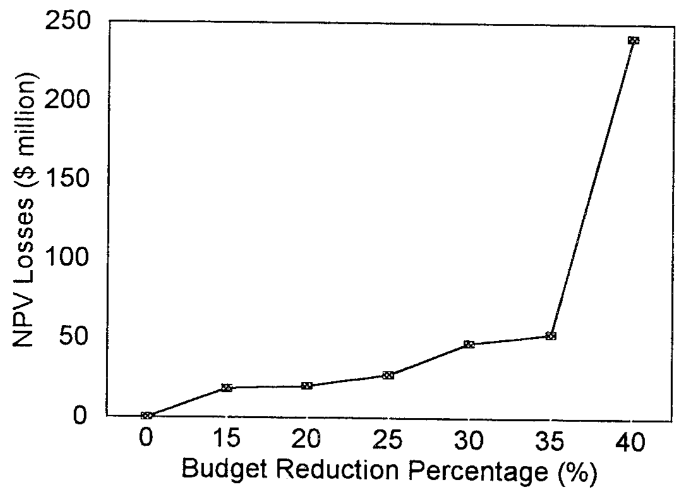

Figure 1. NPV Losses vs Budget Reductions. The NPV losses are less than $50 million for the budget reduction set at less than 35% of $ 441 million but increases sharply after that limit.

The funds requirements were highest in years 1 and 2 in the unconstrained case. Reducing the budget in these two years shifts some closure and realignment actions later thus reducing the NPV savings. We however observed that the reduction in NPV savings is small initially as BRACAS first delays those projects with small net savings. As

the budget is reduced further, projects with large net savings are now affected thus resulting in large reductions in NPV savings. From the above graph, the budget reduction at 35% of $441 million appears to be a good limit beyond which the reduction in NPV savings is very large. This provides a basis to set a budget for the installation closure and realignment actions.

3. Tradeoffs between Budget and NPV

Suppose now that the budget authorities have imposed a budget limit on the BRAC actions and are willing to trade off budget with savings. We could use BRACAS to produce a schedule within these budget constraints and accept the NPV savings that are produced by the schedule. We could also use BRACAS to examine whether the budget is adequate and whether there is a justification to request an increase in the limit because it results in greater returns in savings.

Given a budget limit, BRACAS allows the budget limit to be exceeded when the increased in NPV savings exceed the penalties for budget violation. When the penalty is very large, we have the constrained budget case. When the penalty is small, it is possible for the budget to increase if the savings more than offset the penalties in NPV savings. Given a tradeoff between budget and NPV savings represented by the penalty, BRACAS determines whether there is a need to increase the budget so that more one-time costs can be paid in return for greater NPV savings. Budget violations given an initial budget limit can be determined in this manner.

Figure 2 shows the relationship between budget violations and the value of the penalty. The budget violation represents the increase in budget required. With zero budget penalty, this is the same as the budget requirement in the unrestricted budget scenario and the budget violation decreases with increasing budget penalties.

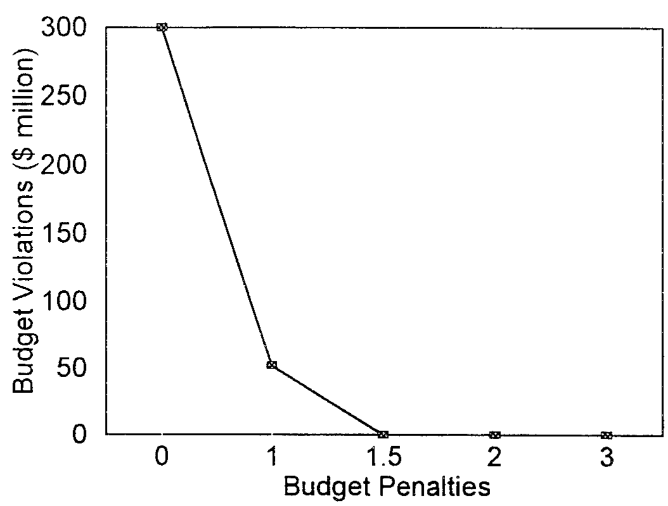

Figure 2. Budget Violations vs Budget Penalties. The budget violations represent the increase in budget when the increase in NPV savings exceeds the budget penalties. The budget violation is $50 million when the budget penalties is 1 and is zero when the budget penalties exceed 1.5.

The budget penalty has an economic interpretation [Bradley, 1986]. The budget penalty is the unit cost in NPV for each dollar violation of the budget constraint. The interpretations for various values of the penalty are:

1. The penalty is zero. There are no penalties for budget violations and one can borrow as much as necessary in order to pay for the present spending. This is the same as the unconstrained budget.

2. When the penalty is greater than zero, this is the penalty for moving expenditures to an earlier year and must be offset by increasing savings that result from implementing the actions earlier. As can be seen from Figure 2 for this scenario, with a budget penalty of greater than zero, budget violations decrease as the penalty increases and becomes zero when the budget penalty is greater than 1.5.

B. PERSISTENCE

Solutions persistence can be obtained by penalizing deviations from the current schedule when BRACAS is run again with updated data. We set up a scenario to test BRACAS' ability to achieve persistent solutions. We also examine to what degree solution persistence changes with the level of the persistence factor.

1. Scenario

In the scenario, an optimal schedule based on prior budget constraints has been generated and the budgets for subsequent years are now reduced. Specifically, the budget in the second and third years are now reduced by 10%. A new optimal schedule is now required taking into account that the first year schedule has already been implemented.

2. Results

We examined the optimal solutions generated by BRACAS when there is solution persistence and when there is not. Recall that changes in the schedule occur when any of the binary variables changes its value. In the absence of persistence, the new schedule produces 87 changes to the previous schedule. With a persistence factor value (defined in

Chapter 3) of 0.5, the changes are reduced to 45. The results of further BRACAS runs with increasing values of persistence values are shown in Figure 3 below. The number of changes becomes insignificant when the persistence value exceeds 5.

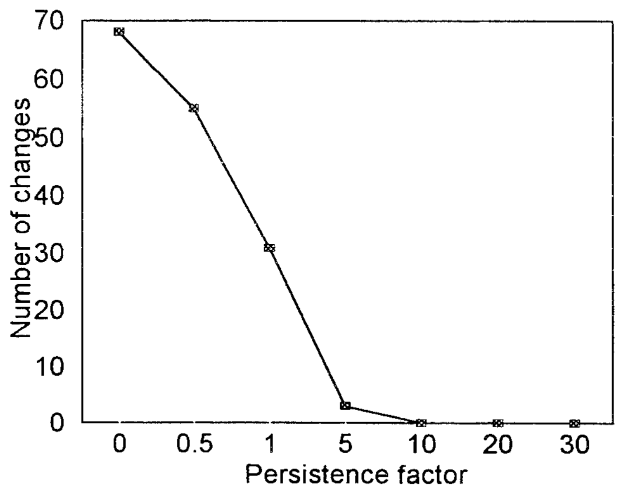

Figure 3. Number of Changes in Schedule vs Persistence Factor. The number of changes in the schedules decrease with increasing values of the persistence factor and becomes insignificant when the persistence factor value exceeds 5.

The reductions in the number of changes brought by higher levels of persistence are not without cost. When changes are reduced further, the original budget level becomes insufficient and have to be eventually increased. Figure 4 below shows the increase in budget with persistence level.

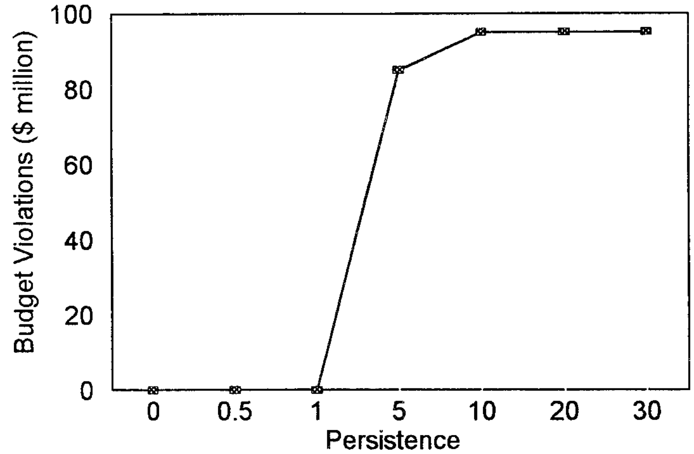

Figure 4. Budget Violations vs Persistence Factor. Budget violation increases to $80 million when the value of the persistence factor exceeds 5.

3. Economic Interpretation

The budget violations due to persistence have an economic interpretation. The cost per unit budget violation (the budget penalty) is set at 1.5. Changes in the schedule are penalized by a multiple of the recurring savings guided by the persistence factor. The budget violation is zero for a persistence level less than one since the budget penalty is greater than the persistence penalty.

When the persistence factor is five, the penalty of each change is five times the recurring savings due to the change. It is now worthwhile to violate the budget as the penalty of the violation, measured by the budget penalty, is less than the penalties due to the changes. For this reason, the budget violation is $82 million and the number of changes to the schedule is kept low.

When the persistence factor is greater than 5, the penalty for budget violation becomes smaller compared to the persistence penalty and so budget violation increases further to $95 millions.

The above test case illustrated how BRACAS achieved persistence in the new schedule when it is generated with updated data. The scenario used is a simple one and we have shown how the changes in the revised schedule can be reduced by increasing the persistence level. We have also shown how the budget eventually has to increase when the changes are reduced. Other scenarios may have changes to the input data other than the budget. BRACAS can generate a revised schedule while reducing the changes to the current schedule to a manageable level. Analysis similar to the one done above could help the decision makers to decide on the number of changes to be made to the original schedule and its budget implications.

C. TESTING OF ALTERNATE SAVINGS FUNCTION

In this section, we use the piecewise linear approximation to the savings function and examine its impact on the model results. The model is implemented using the same data as in the step savings function, generated using GAMS [Brooke, 1994] and solved using XA [Byer, 1992] on a 486/66 personal computer. The model has 2,497 variables, 540 binary variables, and 1,942 constraints. A solution within 5% of optimality was generally constructed within 5 minutes. The model has only 540 integer variables compared to 1464 generated by previous model. In a mixed integer programs, solution time is usually proportional to the number of integer variables.

The schedule produced by the alternate formulation appears to produce results similar to the step function and in a much shorter time. Clearly, the reduced solution time is an advantage of the piecewise linear objective function. Further analysis is required before deciding on the appropriate formulation to be used.

V. CONCLUSIONS AND ENHANCEMENTS

A. CONCLUSIONS

BRACAS is a model that develops an implementation schedule for the U.S. Army installations slated for closure and realignment. It is a mixed integer program that maximizes the NPV of future savings less the one-time costs while satisfying yearly budget constraints. The schedule produced by BRACAS contains a detailed breakdown of costs for each closure and realignment action. BRACAS also takes into account the construction lead time before allowing closing and realignment activities to take place. On a personal computer, a solution within 5% of optimality is constructed within a few minutes.

In addition to constructing an optimal schedule, BRACAS also provides insight on the adequacy of the budget and facilitates analysis of tradeoffs between the budget and NPV savings. BRACAS also ensures substantial similarity with a previous schedule when the model is run again with updated data. This is a useful feature for schedule revision where drastic changes to a previous schedule are not desirable.

We have also examined an alternate formulation of BRACAS using a piecewise linear savings function. Comparisons of results with the step savings function show that the alternate formulation leads to faster solution time. Despite the advantages, further analysis is needed before deciding on the appropriate savings function to be used.

Between June and August 1995, BRACAS and further extensions helped the U.S. Army Base Realignment and Closure Office determine budget levels and implementation

schedules for the 1995 closures and realignments. For these runs, solutions within 0.001% of optimality were generally constructed within 30 minutes using a personal computer. At the time of writing this thesis, BRACAS has undergone further changes to meet their changing needs. This underscores the need for the model to be adaptable to new requirements and changes while it is being used.

B. AREAS FOR FUTURE ENHANCEMENTS

Currently, optimization experts run BRACAS. To encourage its use in the future, a better user interface is required. The interface requirements are as follows:

1. A spreadsheet should serve as an interface between the GAMS codes and the user.

2. It should be able to read input data from COBRA and execute BRACAS.

3. It should be able to read the output from BRACAS and allows the users to conduct what-if analysis.

4. It should allow the users to input scenarios and conduct analysis.

APPENDIX A. DATA ASSUMPTIONS

This appendix contains the assumptions on how the data extracted from COBRA are combined to form the data input to BRACAS. There are also assumptions on how these data are further broken down for each lose-gain pair of installations.

A. DATA EXTRACTED FROM COBRA

1. BRACAS input CONSAV is the cost avoided at the losing installation as a result of a BRAC action. CONSAV includes the following one-time savings from COBRA: military construction cost avoidances; family housing cost avoidances; land sales; one-time moving savings; environmental mitigation savings; and one-time unique savings. All costs avoided are considered as savings realized in year one of the transition period.

2. BRACAS input OTHER is the one-time cost at the losing or gaining installation as a result of a BRAC action. OTHER includes the following costs from COBRA: other; HAP/RSE; environmental mitigation cost; and one-time unique costs.

3. BRACAS input PROGRAM is the overhead and program planning cost at the losing installation. This is the support cost in COBRA. These costs are not under control of the BRACAS model. The total amount paid is initially distributed over four years where each year is discounted by 25%. This is subsequently adjusted based on the actual duration of the BRAC transition of each installation.

4. BRACAS input SHUT-C cost is the mothball and shut down cost at the losing installation. SHUT includes the following costs from COBRA: mothball and shut down.

5. BRACAS input PERS-C is the personnel cost at the losing or gaining installation. For the losing installation it is the severance cost whereas for the gaining installation it is the cost to hire new personnel. PERS-C includes the following costs from COBRA: personnel; civilian RIF; civilian early retirement; civilian new hires; eliminated military PCS; and unemployment.

6. BRACAS input CON-C is the construction cost at the gaining installation. CON-C includes the following costs from COBRA: military construction; family housing construction; information management account; and land purchases.

7. BRACAS input CIVPCS is the cost to move civilian personnel from the losing installation. CIVPCS includes the following costs from COBRA: moving; civilian moving; and civilian PCS.

8. BRACAS input MILPCS from COBRA is the cost of moving military personnel from the losing installation. The average tour length for military personnel on a given installation is 26 months. Therefore, 12/26 of the cost to move military personnel in a given year can be considered to be due to natural rotation and not attributable to the BRAC action.

9. BRACAS input FREIGHT is the cost to move freight from the losing installation. FREIGHT includes the following costs from COBRA: freight; and one-time moving.

10. BRACAS input RECSAV is the recurring savings at the losing or gaining installation which accrue yearly after the completion of all BRAC activities. RECSAV includes the following cost from the COBRA appdet report: recurring net beyond. The RECSAV for a losing installation is positive and for a gaining installation is negative.

11. BRACAS input N-MIL, N-CIV, N-FREIGHT from COBRA are the number of military personnel, civilian personnel and tonnage of freight to be relocated from the losing installation to the gaining installation.

B. DATA MANIPULATIONS IN BRACAS

The above data input are computed for each losing installation and gaining installation.

These data are broken down for each lose-gain pair of installations as follows:

1. REALIGN is the total moving cost, it is the sum of MILPCS, CIVPCS, FREIGHT, OTHER and SHUT-C costs at the losing installation of each lose-gain pair of installations. The computation of REALIGN for each lose-gain pair is based on the proportion of personnel and freight moving from the losing installation to the particular gaining installation.

2. GAIN is the total set up cost, it is the sum of PERS-C and OTHER costs at the gaining installation of each lose-gain pair of installations. The computation of GAIN for each lose-gain pair is based on the proportion of personnel and freight moving from the particular losing installation to the gaining installation.

3. RSAV is the net recurring savings generated for each lose-gain pair of installations when closure or realignment activity is completed For each lose-gain pair, the recurring savings for the losing post (always positive) is based on the proportion of personnel and freight moving out to the particular gaining installation. The recurring savings for the gaining post (always negative) is based on the proportion of personnel and freight moving into it from the particular losing installation. RSAV for each lose-gain pair of installations is the sum of the two recurring savings.

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